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Studies (1973–1978) on the Biological Effects of Low and Extremely Low Frequency Electromagnetic Fields

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When presented with an apparently insoluble and complex methodological problem, a normal and predictable human behaviour is an all-or-nothing response: to reject the phenomenon totally or to accept it without question. Various forms of emotional behaviors, typically displayed in the midst of these phenomena, reduce even further the scientist's ability to discriminate the essential stimulus operations and to evaluate objective changes. Such counterproductive behaviors, antagonized by recent political, popular and psychological factors, have complicated essential research of extremely low frequency (ELF) electromagnetic (EM) field effects. Any review of work generated during 1973–1978 must be evaluated carefully according to precise methodology and absolute changes rather than general conclusions such as 'effect or no effect'.

The ELF label has been used to designate electromagnetic field-waves of 10 Hz ± 1 kHz (0.01 Hz–10 kHz) or pulses within this range from higher frequency waves (Persinger, Ludwig and Ossenkopp, 1973). Traditionally, general biometeorological interest in these particular EM phenomena reflected their: (1) occurrence during various geophysical-meteorological conditions, (2) unusual penetrability and propagation properties, and (3) similarity to EM patterns generated by living systems including man.

Biometeorological-relevant ELF research before 1973 (Persinger, 1974) displayed a rich variety of experimental frequencies, intensities (1 nT–100 mT and 1 mV/m–100 V/m) and wave forms. Unfortunately,

Editor's Note: A summary of the major studies on biological effects of EM fields during the period 1963–1970 was given by Reiter. In *Progress in Human Biometeorology* Part IA. (ed. S.W. Tromp) Swets & Zeitlinger Publ. Co., Amsterdam/Lisse, 1974, 32–33 and 329–334.

within the rich variety, there is little reliable substance. Most of the experiments (i) did not specify elementary (and essential) methodological details, (ii) utilized gross or multiconfounded measurements and (iii) generally appear as fragments of singular hypothesis testing rather than a systematic approach. The field is still kaleidoscopic.

In the last six years, the texture of ELF research has been influenced notably by three main factors: First social concerns, specifically the US Navy's Project Sanguine (Seafarer) and ELF-EM generating 10 000 km^2 grid system, and potential deleterious consequences of high voltage 60 Hz power lines; second, the use of operant behavioral methods of measurement; and third, a renewed interest in 'electromagnetic medicine' for treatment of specific human disorders. Several episodes of media-induced paranoia associated with alleged untoward effects from ELF pulses of MHz signals generated by other countries were evoked in the USA and Canada by individuals not conversant with the scientific literature.

Ten reviews or general articles concerned primarily with pulsed ELF signals or high power sources have been published during this period (e.g. Bridges, 1978; Marino and Becker, 1977; Milroy, O'Grady and Prince, 1974). The most negative summary of ELF-EM effects was the Report of the Committee of 'Biosphere Effects of Extremely-Low-Frequency Radiation', published by the National Academy of Sciences (1977) pursuant to a contract with the US Navy. Allegedly a critical summary of the present status of ELF work, the document contains an extraordinary bias: if a single study did not find any ELF effect, then there is no effect; if a single study did report an ELF effect, then there is no effect.

Three general data patterns have emerged from the ELF literature. The effects of near-natural intensities (nT–μT) or supranatural intensities (μT–10 mT) upon normal adult animals are (i) very small, if present, (ii) can be masked easily by many routine experimental procedures, and (iii) comparable in magnitude to a multitude of background stimuli. For example, research in this laboratory indicated clearly that 5-day exposures of 40 adult male rats to 0:5 Hz magnetic fields between 10 nT and 1 μT variation did not influence significantly: (i) any of 20 different blood measures determined automatically by computer (Persinger *et al.*, 1978a), and (ii) circulating blood T3 and thyroxine levels or thyroid follicle and mast cell numbers (Lafrenière and Persinger, 1978). Similarly, 48 adult female rats exposed for 10 days to 0.5 Hz variations between 0.1 μT and 1 mT displayed no discernible changes in thyroid morphology or other tissue wet weights (Persinger, Lafrenière and Carrey, 1978b). Significant interactions between pre-exposure housing conditions and ELF-EM field intensities were evident for serum glutamate oxaloacetic transaminase activity and for thyroid and spleen weights in these studies.

A continuation of this pattern has been noted in human and non-human behavioral measurements recorded during acute (short-term) ELF exposures. In fact, the earlier reports by König (1971) and by Hamer (1968), who reported significant changes in reaction time (RT) during 2–12 Hz, 1–4 V/m field presentations, have not been replicated clearly by other experimenters. Persinger, Lafrenière and Mainprize (1975) exposed 70 male and female human subjects during 40 min sessions to successive 10 min presentations of either 3 Hz or 10 Hz electric fields of 3.0 V/m, 0.3 V/m or sham conditions. No statistically significant differences in mean RT were associated with any of the field conditions; in fact, 99% of the variance in mean RTs could be explained by: (i) duration within the experimental paradigm, (ii) individual differences, (iii) sex differences and (iv) RT stimulus (a light) presentation pattern. The last three factors plus field condition did contribute to the standard deviation of RTs in a small but significant manner.

As aptly stated by de Lorge many times, the more controlled the behavioral paradigm, the less likely any ELF-associated effects are observed. There is a clear difference between the earlier anecdotal experiments used to prove personal hypotheses and systematic research, as de Lorge's research demonstrates. In a series of well designed and executed experiments involving monkeys, rats and pigeons exposed for periods of hours up to days to a variety of ELF frequencies (7–75 Hz) and intensities (0.1–10 mT; 1–30 V/m), de Lorge and his colleagues (de Lorge and Grissett, 1977) have found no reliable change in the several operant measures employed.

Although normal adult mammals have not responded systematically to experimental ELF-EM fields, some aquatic or avian species have displayed reliable effects. The motility of protozoa (Friend, Finch and Schwan, 1975) and the mitosis of microplasmodia from slime mold (Goodman, Greenbaum and Marron, 1976) have shown alterations during applications of ELF fields around 1 V/m and 0.1 mT. Several experiments by Southern (1975) and Larkin and Keeton (1976) strongly indicate that ELF-EM fields affect bird orienting responses. Whether these changes reflect real species differences or methodological approaches has not been evaluated.

The second general pattern of ELF data originates from experiments involved with field parameters far exceeding typical meteorgenic ELF values or forms, specifically: (i) 50 or 60 Hz fields comparable to energy values of several kV/m, and (ii) energetic microwave or radio-frequencies pulsed within ELF ranges. The majority of well-designed high voltage experiments in the USA have been reported by Marino and Becker and their colleagues (Marino *et al.*, 1977). Their studies indicate that long-term exposure of mice to 60 Hz fields of 150 V/cm induced

alterations in body weight and several blood measures characteristic of general 'stressors'.

The microwave-pulsing approach is typified by the experiments of Adey and colleagues (Bawin, Gavalas-Medici and Adey, 1973) who found that 147 MHz, 1.0 mW/cm^2 fields, amplitude modulated at 0.5–30 Hz (ELF pulses) elicited obvious post-exposure electroencephalographic changes in cats. Although both lines of research offer exciting challenges to the general problems of electromagnetic noise in the twenty-first century, and, especially the unspecified complications of microwave power applied in ELF pulses to the nervous system, they are secondary to the scope of classical biometeorology. Synergisms between man-made EM noise and geophysical-meteorological ELF fields are a theoretical necessity; their practical demonstration is an empirical nightmare.

A renewed interest in 'electromagnetic medicine', a concept that has been entertained and discarded several times within western culture, comprises the third data pattern. The implicit assumptions of most magnetotherapies is that EM fields normalize or reduce symptoms of low-level heterostasis, typical of those paired to weather changes. General discussions of this concept have been published by Ludwig (1977) and Von Warnke (1978).

Space does not permit proper evaluation of the many laboratories in Europe, Asia and North America involved with some form of weather-related ELF magnetotherapies. One of the more serious series of experiments has been conducted by Ludwig and his colleagues. Displaying a rare integration of theoretical conception, technical development and experimental testing, Ludwig has: (i) used special electromagnetic screening to evaluate the contribution of ambient atmospherics to arthritic complaints (Ludwig, 1973), (ii) developed portable, pocket-sized ELF generators to allow greater mobility of experimental subjects, and (iii) tested the therapeutic value of weather-like ELF pulses (Ehrmann *et al.*, 1976). Although Ludwig and his medical colleagues appear conversant with placebo problems and utilized blind controls in their procedures, the extraordinary sensitivity of the symptoms most influenced by magnetotherapy of a multitude of non-verbal cues must temper generalization at this time. Replication of these effects in several different laboratories, preferably by experimenters negative to ELF magnetotherapy is essential.

The introduction of one final major concept – pharmacological enhancement – could change the probationary status of ELF fields as biometeorologically relevant stimuli. This operation assumes that some optimal drug treatment to living systems before or during the presentation of elsewise ineffective ELF fields, will enhance negligible organismic alterations to large and replicable magnitudes. Until this

phenomenon is demonstrated, however, ELF-EM effects in biometeorology must remain within the vast heterogenous pool of low-level background stimuli that occasionally emerge from the normal variability of biobehavioral measurements.

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